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Abstract: As part of a 1980-82 study, the flight behavior and mortality of sandhill cranes (*Grus canadensis*) was studied at 4 alkaline lake sites in central North Dakota. We analyzed the behavioral response of sandhill cranes in flight at powerline sites and examined factors associated with collisions with a power line structure. Several methods that can be used to reduce crane mortality at power line sites are discussed. Findings of several other research efforts that address crane mortality at power lines are summarized.

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Collisions with power lines are an important mortality factor among several bird species (Drewein 1973; Brown et al. 1987; Faanes 1987). Although no biologically significant mortality has been identified at any individual site studied. the cumulative impact of mortality across a species' range has not been fully calculated. Most authors agree, however, that mortality from power lines is a potentially important limiting factor among endangered species (Anderson 1978; Lee 1978; Faanes 1987). Successful recovery of the endangered whooping crane (*Grus americana*) is dependent in part on development of protective measures to reduce collisions with power lines (U.S. Fish & Wildlife Service 1986). Because of similarities in body size and flight characteristics, sandhill cranes often are used as surrogates or correlative models to assess potential impacts of various factors on whooping cranes (Ward et al. 1987). Despite heightened public awareness and a clear need to reduce power line mortality, few studies have been conducted to examine mortality among crane species (Brown et al. 1987; Howard et al. 1987).

An intensive study of mortality among several bird species was conducted at waterbird concentration areas in central North Dakota during 1980-82 (Faanes 1987). Specific objectives were to 1) determine the magnitude of bird mortality, and 2) identify factors contributing to mortality. Sandhill cranes were among the most numerous bird species observed at power line sites and also among birds found dead. In this paper, we analyze the sandhill crane data and compare our findings with efforts of other investigations. We also discuss the usefulness of various techniques for reducing mortality from power lines among sandhill cranes and whooping cranes.

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STUDY AREA

Detailed descriptions of the 4 sites studied are provided in Faanes (1987). The sites were characterized by the presence of large alkaline wetlands (class V of Stewart & Kantrud 1971). Habitats surrounding the study sites were a mosaic of native grasslands, wetlands of various classes, and cropland. Wheat (*Triticum vinter*) farming and summer fallow were the predominant agricultural land uses.

Three of the 4 study sites were traversed by single-circuit 230 kv AC power lines. The lines were in a flat configuration suspended on self-supporting steel lattice towers. The Sibley Lake site was traversed by a bipolar 400 kv DC line (4 conductors in 2 bundles) in a flat configuration, suspended on self-supporting steel lattice towers.

From late August to early November, the sandhill crane was the most numerous bird species using most sites. Peak waterfowl numbers occurred during mid-September to early November, being primarily Canada geese (*Branta canadensis*), snow geese (*Chen caerulescens*) and mallards (*Anas platyrhynchos*). Franklin's gulls (*Larus pipixcan*) were numerous at Kunkel Lake, and a large colony of American white pelicans (*Pelecanus erythrorhynchos*) nested at Chase Lake. Several species of shorebirds occurred in varying numbers throughout the migrational periods.

METHODS

Data were collected in each study area to determine bird movements, flight intensities, behavior and reactions to power lines. Observations were made during early morning (0.5 h before sunrise to 0900 h) and evening (2 h before sunset to 0.5 h after). Nocturnal observations were conducted during fall 1980 but were subsequently discontinued because few birds were observed at night.

We recorded the numbers of birds passing above, beneath and through the power lines, and behavior. Data collected for each flight of birds observed included altitude, reaction of the bird(s) to the presence of ground wires or-conductors, the distance from the power line where the bird(s) reacted to the presence of ground wires or conductors, and the altitude maintained by the bird(s) after passing the exit zone. The exit zone was that portion of airspace 15 m away from the ground wires or conductors.

Data collected for each flight of birds approaching the power lines were time of day, flock size, species or type of bird, approach height, crossing height and exit height. Height above ground was divided into 6 categories: Zone 1 — ground level to the base of the conductors; Zone 2 — area between conductor and ground wire; Zone 3 — zero to 3 m above; Zone 4 — 3 to 8 m above ground wire; Zone 5 — 8 to 15 m above ground wire; and Zone 6 — >15 m above ground wire. Reactions by birds in flight were categorized as (1) no reaction, maintained constant altitude and unaltered flight; (2) flared and crossed higher than original altitude; (3) aborted flight upon seeing power line, reversed flight, and continued flying away from power line (usually < 50 m from the power line); (4) flared and continued to climb after crossing into the exit zone; (5) turned and left area (usually > 50 m away from the power line); (6) flared from power line and left area (usually occurred within 50 m of the power line); (7) collide with a structure.

Most study sites were searched for dead birds twice weekly during spring and fall, with study periods including July-November 1980, April-May 1981 and 1982 and August-November 1981. Portions of the upland along each study segment were searched by 2 observers walking in zigzag patterns under 1 line and returning under adjacent areas. Lengths of search areas varied from 1.1 to 1.8 km. Search widths extended 45 m outward from the center conductors. Two study sites were searched each day, generally between sunrise and 1000 h. Search times were alternated so each site was visited at dawn at least once weekly. The location of each dead bird or feather spot (a group of feathers remaining after scavenging or decomposition) found was marked on a map of each study site. Dead birds and feather spots were collected and removed from the area during each search.

All birds found dead or injured under the lines were examined to determine the probable cause of death or injury. Data recorded for each bird found included species, sex, age, physical condition (broken bones, lacerations, abrasions) and other observable signs of death or injury, including gunshot wounds.

RESULTS

Flock Size - We observed 964 sandhill crane flocks in flight at power lines (Table 1). Mean flock size was 24.5 birds and individual flocks ranged from 1 to 1,000 birds. There was virtually no difference in flock size among years. Data in 1982 are only from spring migration when sandhil] cranes do not congregate in large groups in central North Dakota (Johnson & Stewart 1972). Numbers of sandhill cranes peaked during 21-30 September each year (Faanes 1987).

Bird Flight Behavior - We analyzed the behavior of 961 sandhill crane flocks in flight. Most (75.6%) showed no reaction to the lines, 15.1% aborted their flights (Table 2), and birds that apparently observed the power line structures, > 50 m away, turned and continued to fly from the site made up 7.3% of the total. Over one-half of the sandhill cranes observed flying at a power line were 0-3 m above the ground wire (tower zone 3) (Table 2), and 26.4% were 3-8 m above (tower zone 4).

Changes in altitudes of sandhill cranes in flight at the study sites are depicted in Table 3. In all instances, the mean altitude maintained by flocks crossing power lines was greater than the mean approach altitudes. The differences in 9 flocks between those approaching a power line and those crossing or exiting is due to flocks that aborted flights and left the area. Approach altitudes were highly significantly related to flock size ($P = 0.0003$). Windspeed also significantly affected approach altitude ($P < 0.01$) (Table 4).

Dead Birds - We observed 3 sandhill cranes collide with power line structures, all hitting the ground wire. Two of those exhibited no reaction to the presence of a power line prior to colliding, and one flared and was climbing when it collided. Sixty-two sandhill cranes were found dead heneath power line structures. The seasonal breakdown included 4 birds in spring and 58 during fall migrations. The number of dead cranes was greatest at Sibley Lake where 40 were found, representing 65.5% of the total.

Physical evidence of a collision with a solid object was found for 52 dead sandhill cranes; cause of death for the remaining 10 birds was unknown. Typical injuries included broken necks, broken wings, broken legs, lacerations, abrasions and decapitation. Sixty of the 62 cranes were found within 3 days of death.

Impacts To Whooping Cranes - Lingle (1987) identified power lines near roost sites and feeding areas as important hazards to migrant whooping cranes. We recorded no whooping cranes at our study sites, but at least 15 instances of whooping cranes colliding with power lines were reported during 1956-1987, most of which were immatures (U.S. Fish & Wildlife Service 1986). Data were recorded on the type of line where 8 birds collided, and in each instance the lines were < 115 kv, i.e. power distribution lines. An immature whooping crane that collided with a power line near Glaslyn, Saskatchewan, was observed to flare near the line prior to collision.

DISCUSSION

Sandhill cranes regularly collide with power lines wherever the species occurs in abundance, including North Dakota (this study), Colorado (Brown et al. 1987), west Texas (Tacha et al. 1979), Nebraska (Wheeler 1966) and the southern portion of the Central Flyway (Lewis 1974). At least in whooping cranes, immatures and subadults are more susceptible than are adults (Brown et al. 1987).

Faanes (1987) suggested that mortality among sandhill cranes at power line sites may be related to the juxtaposition of power line corridors and the location of roosting and foraging areas. Natural drainageways that tend to funnel birds through an area supporting one or two power line spans appear to influence collision mortality. In west Texas, Tacha et al. (1979) reported considerable sandhill crane mortality where birds followed well-defined flight lanes between foraging and roosting areas. Walkinshaw (1956) mentioned a similar situation in western Nebraska. Brown et al. (1987) observed that flight reaction and reaction types were related to proximity of the lines to feeding areas; the highest proportion of birds reacting to the power line were within 25 m of the line and adjacent to a feeding site.

Our flight behavior data suggest that most sandhill cranes are unaware of the presence of the power line. Over 75% of the sandhill crane flocks we observed flying near a power line exhibited no reaction to its presence. Brown et al. (1987), on the other hand, reported almost exactly opposite percentages, with about 71% of the cranes in flight having flared and adjusted thelr fllght to avold power line structures. Anderson (1978) reported that collisions of mallards at an Illinois study area most regularly occurred after birds had been startled into flight.

Site-specific collision mortality may not be biologlcally significant to populations of common bird species across a species' range. Endangered species, on the other hand, may be impacted seriously if even 1 individual dies from a collision. Brown et al. (1987) reported that 39% of all known losses of whooping cranes in the experimental Rocky Mountain flock were killed or incapacitated by collisions with power lines, and Drewein (1973) concluded that 37% of the known mortality in the Rocky Mountain sandhill crane population was the result of power line collisions.

Apparently a strong relationship exists between the visibility of power line structures and both the frequency and magnitude of collisions by cranes and other birds (Brown et al. 1987; Faanes 1987). Inclement weather and reduced visibility may exacerbate the problem. Brown et al. (1987) reported that inclement weather was a primary factor contributing to the frequency of collisions at a southern Colorado study area. Lee (1978) reported similar findings in the Pacific Northwest. According to the definitions described by Faanes (1987), collision mortality among sandhill cranes is socially significant, and among whooping cranes it is biologically significant. Biologists and utility companies continue to study the issue with an eye to identifying actions that can reduce mortality: Faanes (1987) and others have suggested 3 principal strategies for reducing collision mortality: (1) ground wire removal, (2) placement of colored marker balls on the ground wire, or (3) increasing the apparent thickness of the ground wire by placing spiral vibration dampers or other plastic material on the wire.

However, subsequent research by Brown et al. (1987) suggested that the third option may be an important alternative technique.

Increasing line visibility may be the most prudent alternative for reducing collision mortality among birds. Beaulaurier (1981) reported that after line visibility enhancement, mortality among all bird species was reduced an average 45% at 17 study sites across the northern hemisphere. Installation of colored marker balls and other objects to increase the visibility of the ground wire resulted in a 43% mortality reduction among red-crowned cranes (*Grus Japonensis*) at 1 Japanese site (reported in Brown et al. 1987). Mortality among owls (Strigidae) and tree sparrows (Ploceidae) in Korea was eliminated after placement of 9 x 90 cm red vinyl plates on a power line (Won 1986).

Ground wire removal is the most effective technique for reducing mortality at power lines. Beaulaurier (1981) indicated that bird collisions with power lines were reduced 35 and 69% at 2 Oregon study sites after ground wire removal. Brown et al. (1987) reported a 67% reduction in mortality after ground wires were removed from 4 power line spans, and Faanes (1987) estimated that removal of the ground wire along 1 span would have reduced mortality by 80% at one North Dakota study site.

Ground wires are placed on power line structures to protect the systems from lightning strikes, so ground wire removal over extensive areas may be feasible only in regions such as the Pacific Northwest where lightning strike frequency is low. Extensive ground wire removal may not be a viable alternative in areas such as the Rocky Mountains, Midwest or Southeast which experience high lightning strike frequencies.

We believe it is now appropriate to set standards for reducing mortality at all power lines constructed in the future that may impact bird populations. Areas where mortality is likely to be appreciable can be identified and actions can be taken to reduce mortality at those sites.

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Table 1. Distribution of sandhill crane flocks among study sites in North Dakota.

	Flock Size		
Site	$\overline{x}$	SD	N
Chase Lake	17.7	32.1	86
Kunkel Lake	17.6	40.7	372
Cherry Lake	8.9	8.8	32
Sibley Lake	32.2	43.4	474
Mean	24.5	41.5	964

Table 2. Reactions of sandhill cranes in flight as a function of tower zones at central North Dakota power line study sites.

	Reaction							
Tower zone	None	Flare and cross higher	Abort	Flare and continue climb	Turn and leave > 50 m	Flare & leave < 50 m	Total	%
1	2	0	1	1	0	0	4	0.4
2	22	3	4	0	0	3	32	3.3
3	339	4	92	6	63	0	504	52.4
4	214	0	33	0	7	0	254	26.4
5	108	0	13	2	0	0	123	12.8
6	42	0	2	0	0	0	44	4.6
	727	7	145	9	70	3	961	
%	75.6	0.7	15.1	0.9	7.3	0.3		

Table 3. Changes in altitudes (in meters) among sandhill cranes in flight at power line sites in central North Dakota.

	Approach			Cross			Exit		
Study Site	$\overline{x}$	SD	N	$\overline{x}$	SD	N	$\overline{x}$	SD	N
Chase Lake	26.5	8.1	86	26.8	7.8	86	26.8	7.8	86
Kunkel Lake	23.6	5.7	372	24.7	5.0	371	24.7	23.5	371
Cherry Lake	29.3	10.9	32	29.8	10.6	31	29.5	10.9	31
Sibley Lake	21.7	3.3	474	22.6	2.7	467	22.3	3.0	67

Table 4. Changes in altitudes (in meters) among sandhill cranes in flight at power line sites in North Dakota related to windspeed.

	Approach			Cross			Exit		
Windspeed	$\overline{x}$	SD	N	$\overline{x}$	SD	N	$\overline{x}$	SD	N
Calm	22.6	6.9	153	23.9	6.3	149	23.3	6.7	14
1-5 km/h	22.9	4.5	645	23.8	3.8	641	23.9	4.0	641
6-15 km/h	23.9	6.7	159	24.6	6.5	159	24.1	6.8	159
≥ 16 km/h	31.8	16.4	7	34.0	16.7	6	34.0	16.7	6
$\overline{x}$ =	23.1	5.6	964	24.0	5.0	955	23.9	5.2	955